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Erbium-doped fluoride microstructured fibers for 2.8 μm lasing

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INTRODUCTION & AIM

Lasers with a wavelength of 2.8 μm can effectively resonate with the vibrational energy levels of chemical bonds such as O-H and N-H, and hold important application value in biomedical detection, aqueous system analysis, polymer precision processing and molecular spectroscopy characterization. Rare-earth-doped fiber lasers show broad application prospects owing to their high reliability, compact structure and favorable heat dissipation performance. Fluoride fibers are capable of generating laser emission covering the wavelength from visible light to 3.9 μm, with the maximum output power reaching tens of watts. Currently, the achievement of 2.8 μm lasers mainly depends on the Er: ZBLAN fiber system. Fluoride microstructured fibers feature excellent mid-infrared transmission performance and tunable structural properties, and their air-hole structure can enhance the light-matter interaction and facilitate sufficient contact between the fiber and gaseous substances, thus endowing such fibers with significant application potential in mid-infrared gas sensing, trace gas analysis and other fields. In this paper, Er-doped fluoride microstructured fibers are prepared by the stack-and-draw method, and stable laser output at 2.8 μm wavelength is successfully obtained based on the gain fiber, which provides a feasible technical solution and experimental support for the development of high-performance mid-infrared fiber laser sources.

METHOD

The Er^{3+}-doped fluoride microstructured fibers (Er^{3+}: FMF) were fabricated via the stack-and-draw technique. Firstly, the Er^{3+}-doped fluoride fiber preform prepared by the suction-casting method was drawn into a thin rod with an outer diameter of 2 mm. Meanwhile, a hollow glass tube was drawn into a capillary with an outer diameter of 2 mm. Afterwards, the preform thin rod was stacked together with six such capillaries and assembled into a jacketing glass tube with an inner diameter of approximately 8 mm, followed by the subsequent fiber drawing process.

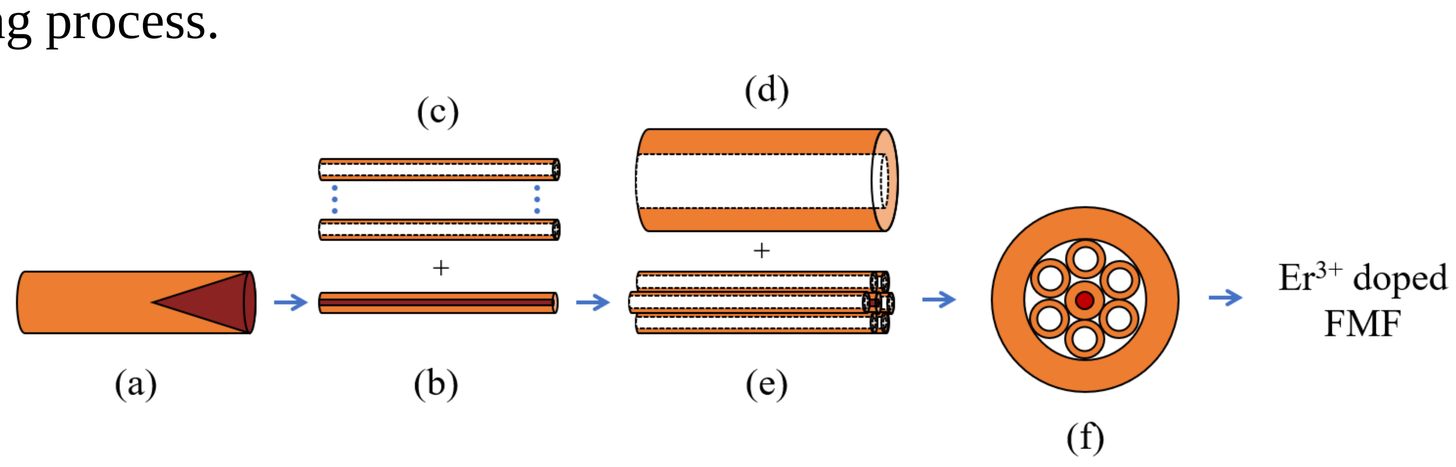

Fig. 1 Fabrication process for Er^{3+}-doped fluorozirconate microstructured fiber.

The experimental setup for 2.8 μm laser emission employs a 976 nm LD as the pump source. The pump beam is coupled into the core of the Er^{3+}: FMF via a set of aspheric lenses. The Er^{3+}: FMF with a length of 62 cm acts as the gain medium, and both ends of the fiber are ground into flat end. A dichroic mirror is closely attached to the pump injection end of the fluoride gain fiber, which exhibits high transmission for 976 nm pump light and high reflectivity for 3 μm band light. The output end of the Er^{3+}: FMF is connected to a power meter and a spectrometer respectively, for the measurement of the laser signal.

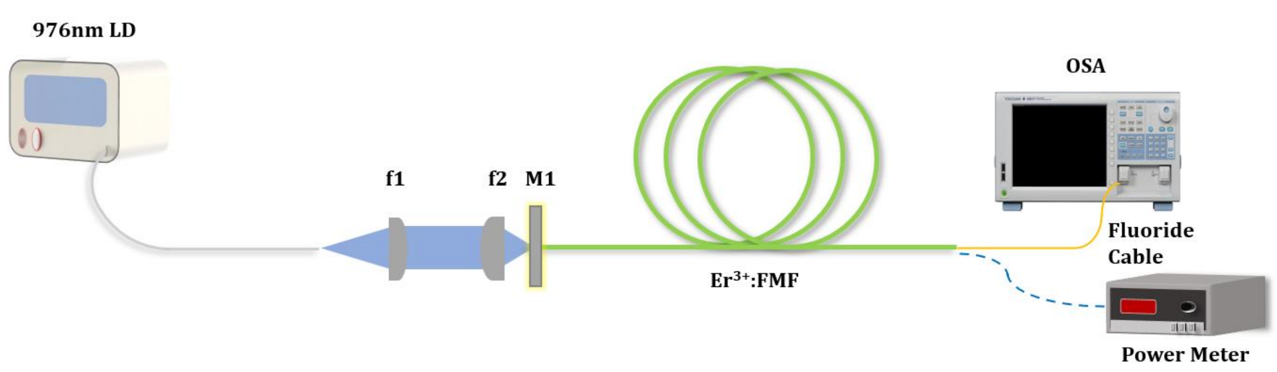

Fig. 2 Experimental setup for 2.8 μm laser generation in Er^{3+}: FMF.

RESULTS & DISCUSSION

Fig. 3 shows the end-face scanning electron microscope (SEM) image of the Er^{3+}: FMF. The area surrounded by the gray line in the middle represents the fiber core, with a core size of 22 μm and a cladding size of approximately 45 μm. Basically, the fiber end face maintains the structural design of the preform. However, due to thermal drawing, the capillaries adhere to the outer tube and stretch, exhibiting an elliptical structure. Benefiting from the air-hole design of the microstructured fiber, the overlap integral factor of pump and signal light can be regulated. In addition, a layer of cladding can prevent external moisture and dust in the air from adhering to the core surface, thereby ensuring the stability of fiber performance. A single-mode fiber laser with a wavelength of 1980 nm was used as the pump source, and the cut-back method was employed to measure the transmission loss of the Er^{3+}: FMF, which was approximately 2 dB/m.

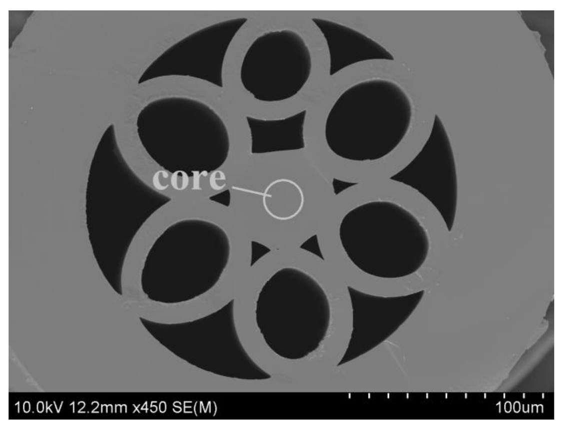

Fig. 3 SEM image of the end face of Er^{3+}-doped fluoride microstructured optical fiber.

Fig. 4 (a) shows the variation of the 2.8 μm laser output power with the pump power. After the pump power exceeds the threshold, the laser output power exhibits a favorable linear growth trend with the increase of pump power. Fig. 4 (b) presents the corresponding spectral profile when the laser reaches the maximum output power of 65 mW, where the central wavelength of the laser is 2716 nm with a spectral linewidth of 1.6 nm. By fitting and calculating the relationship curve between the output power and the pump power, the slope efficiency of this laser is determined to be 16.7% and the laser threshold is measured to be 442 mW.

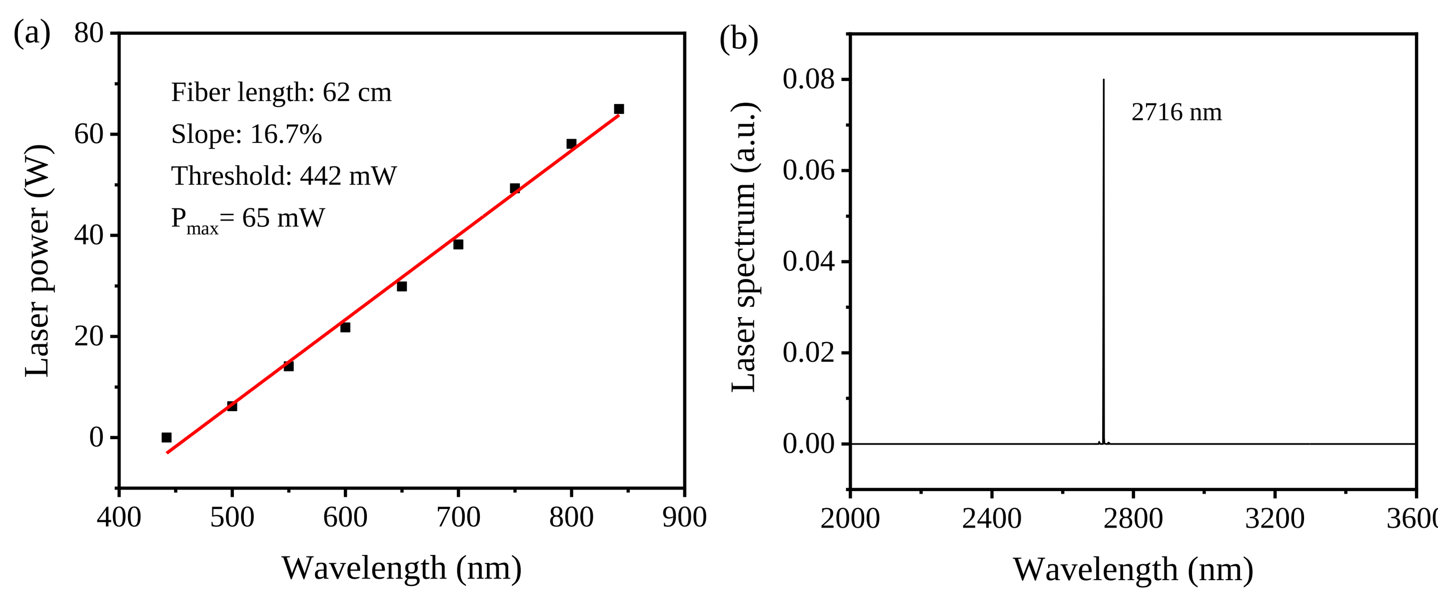

Fig. 4 (a) Variation of laser power with pump power; (b) Output laser spectrum.

CONCLUSION

In this work, 2.8 μm laser is generated in a fluoride microstructured fiber for the first time. The developed fabrication technique provides crucial technical references and experimental support for the precise regulation of optical parameters such as dispersion and nonlinear coefficient for this type of fibers.

FUTURE WORK / REFERENCES

In future work, we will focus on reducing the transmission loss of FMFs, and further improving the output performance of 2.8 μm lasers. Furthermore, the interaction mechanism between the optical field inside microstructured fibers and gaseous media will be deeply explored to expand the application potential of such wavelength fiber lasers in gas sensing and other related fields.